# Comparison of source localization for the P30m, P50m, and N100m peaks of the auditory evoked fields

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## 1 Introduction

N100m is the most prominent peak of the auditory evoked magnetic field (AEF) for tone burst stimulus and has been termed the long latency component. The source of the N100m is considered to be located in the primary auditory cortices along the bilateral superior temporal planes [1]. However, recent studies have suggested a possible contribution of the higher functional areas to N100m generation [2].

P50m is a deflection occurring before N100m in the AEF for tone burst stimulus. P50m is often called the middle latency component of the AEF. P30m is also called the middle latency component of the AEF, and is best elicited with different stimulus procedures such as clicks [3-5]. Both P30m and P50m have smaller amplitudes than N100m. These peaks are believed to originate in or near the primary auditory cortex [3,5-8], and previous magnetoencephalography (MEG) studies suggested that their sources are located more anterior to the N100m source [4-7]. However, these studies have used a limited number of subjects [5], a limited number of sensor channels [4, 5], or presented insufficient data [6, 7]. In the present study, the sources of the P30m, P50m, and N100m components of the AEFs were compared using a helmet-shaped MEG system combined with magnetic resonance (MR) imaging in a relatively large number of normal subjects.

## 2 Methods

The subjects were 27 normal volunteers including 21 males and 6 females, aged from 22 to 66 (mean 32.3) years old. All were right handed and had no history of auditory or neurological diseases. AEFs were recorded with a whole helmet-shaped MEG system (Neuromag 122, Neuromag Ltd., Helsinki) which consists of 122 sensor coils uniformly arranged on the inner surface of a liquid helium-filled, helmet-shaped dewar vessel. Each sensor coil forms a planar-type first order gradiometer with a 16.5 mm baseline. Pairs of sensor coils are aligned to detect the magnetic field gradient parallel to latitudinal and longitudinal lines at 61 sites covering the patient's head. Measurements were performed in a magnetically shielded room. The AEF for the unilateral ear stimulation was recorded in the awake state for the left and right ears independently.

First, in all subjects, monaural tone burst stimuli of 2000 Hz, with 60 ms duration including 10 ms rise and fall time, were delivered at 80 dB sound pressure level (SPL) to the unilateral ear through a plastic tube terminating in a molded ear insert. The stimulus intervals were randomized at 0.3 Hz on average with 30% interstimulus variance. Masking white noise of 50 dB SPL was delivered continuously to the opposite ear. The MEG signal was sampled at 1250 Hz and extracted through a 0.03 Hz to 400 Hz band-pass filter. The data from 500 ms before to 500 ms after the stimulus onset was averaged 50 times. The averaged data was stored in the workstation for later off-line analysis. A low-pass filter was used at 60 Hz. A high-pass filter was used between 0.03 Hz (at data acquisition) and 2.0 Hz.

Second, in 10 subjects, alternative square waves of 1 ms duration at 0.6 Hz were delivered at 80 dB SPL to the unilateral ear using the same stimulation parameters. The data from 500 ms before to 500 ms after the stimulus onset was averaged 512 times. Later off-line analysis used the same parameters as in the tone burst study.

The P30m, P50m, and N100m responses were visually identified as a dipole pattern in the iso-field maps, distributed over the temporal region as a pair of influx and outflux magnetic field peaks (Fig. 1B). If two clear peaks were observed in the middle latency period for the tone burst stimulus, the later peak was defined as the P50m according to a previous report [6]. The location of each source was estimated at the peak latency, using an equivalent current dipole (ECD) model with the best fit sphere for each subject's head.

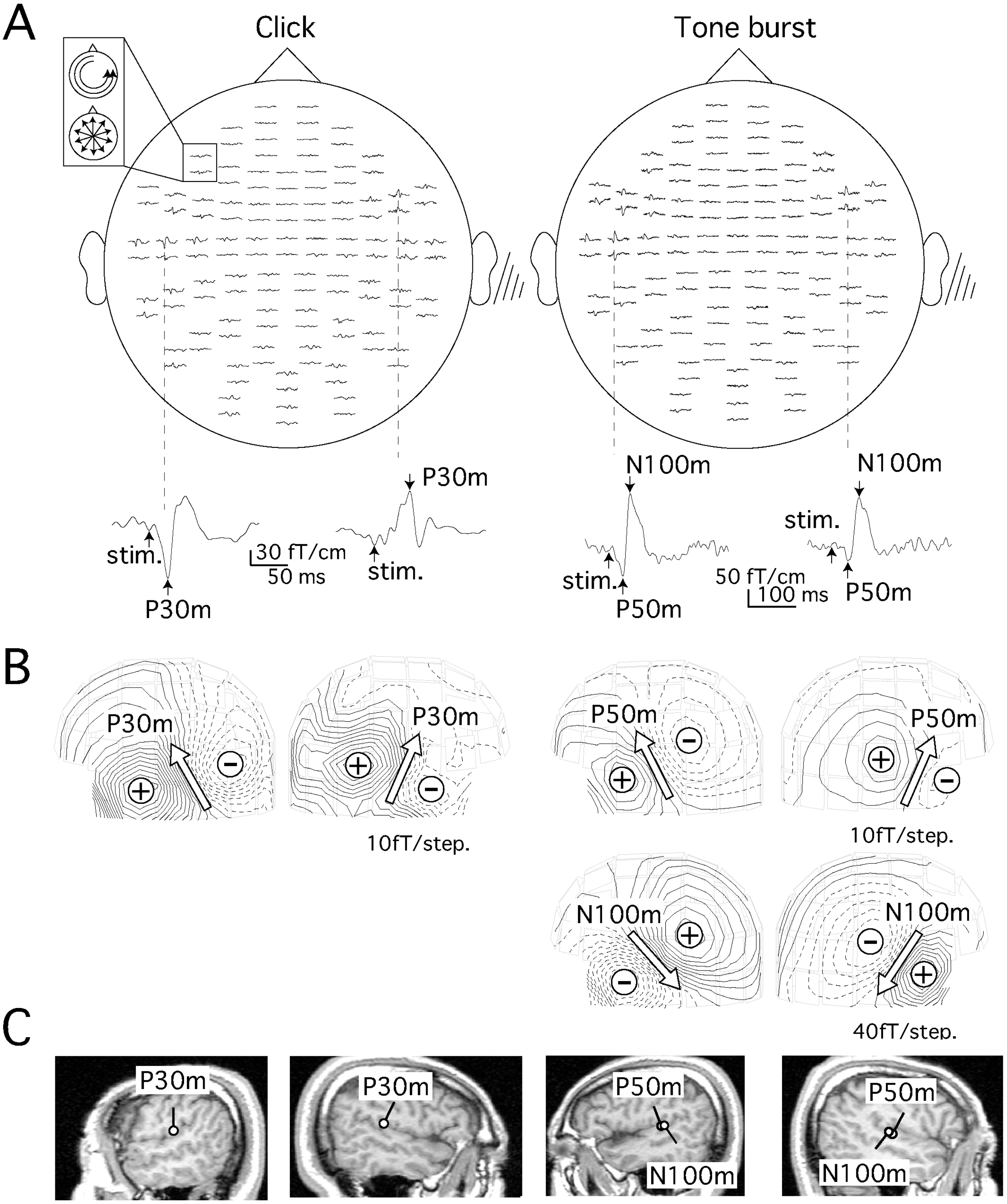

Figure 1: *Auditory evoked magnetic fields for click (left column) and tone burst (right column) stimulus to the right ear in a normal subject. (A) Averaged waveform of the signals recorded in 122 channels viewed from above. Upper and lower traces of each pair represent the latitudinal and longitudinal field gradients, respectively. Bandpass filter of 0.03 to 60 Hz was used for the measurement. No high-pass filter was used. (B) Isofield map of the P30m, P50m, and N100m responses. Arrows indicate the approximate positions of the equivalent current dipoles (ECDs). (C) ECDs superimposed on the magnetic resonance images. Note the very similar positions (circles) of the ECDs for P30m, P50m, and N100m.*

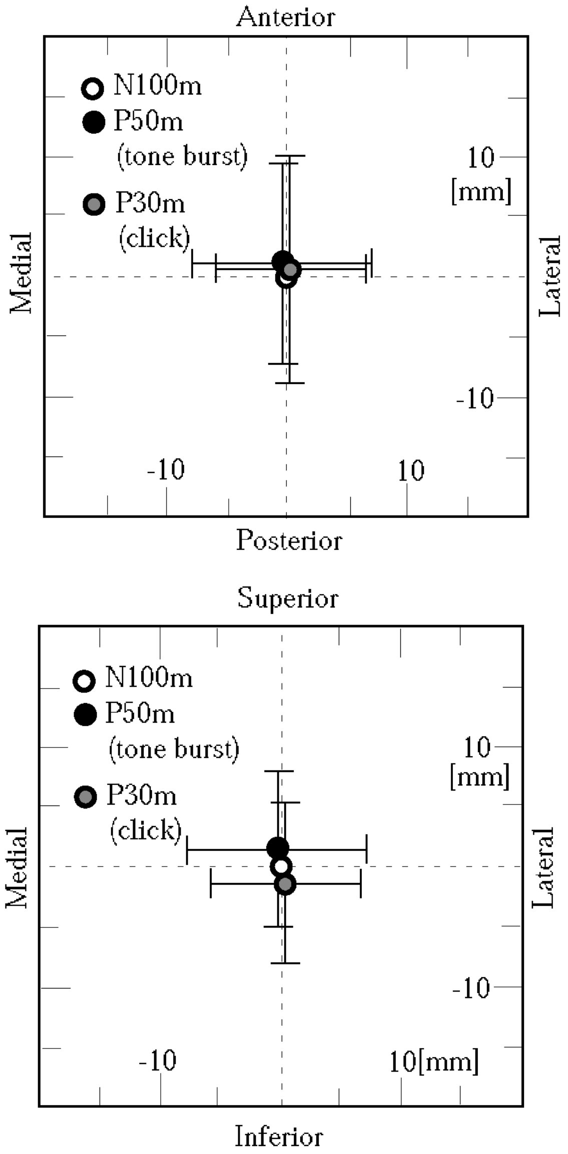

Figure 2: *Summary of the P30m (n=40) and P50m (n=90) dipole positions relative to the N100m dipole position (n=108). Mean and standard deviation are shown for both contralateral and ipsilateral responses for both left and right ear stimuli. There is no statistical difference between the P30m, P50m, and N100m source positions.*

A double-dipole model was used to calculate the bilateral sources on each hemisphere when both contralateral and ipsilateral responses were found. A single-dipole model was applied for one hemisphere when the response was absent in the other hemisphere. The ECD peak latency was calculated for the modeled ECD with a maximum goodness-of-fit of greater than 0.80. Sources were superimposed on the three-dimensional MR images of individual subjects using a MEG-MR imaging coordination integration system based on three fiduciary points, the nasion and the bilateral pre-auricular points, to integrate the two sets of coordinates. The paired t-test was used to analyze statistical differences between P30m, P50m, and N100m source positions in the hemispheric response of either the left or right hemisphere to either contralateral or ipsilateral ear stimulus.

## 3 Results

For tone burst stimulus, clear dipole patterns of the N100m were found in both hemispheres for both left and right ear stimuli (108 responses in all 27 subjects). Clear dipole patterns of P50m were not found in all subjects (90 responses). Orientations of P30m and P50m were opposite to that of N100m (Fig. 1). For click stimulus, clear dipole patterns of the P30m were found in both hemispheres for both left and right ear stimuli (40 responses in all 10 subjects). Latency of the P30m, P50m, and N100m responses was 37.3 ± 9.7 (mean ± SD) ms, 43.6 ± 7.6 ms, and 86.9 ± 12.3 ms for the contralateral responses; and 39.2 ± 12.6 ms, 53.7 ± 10.3 ms, and 99.7 ± 12.4 ms for the ipsilateral responses.

P30m and P50m dipole positions relative to the N100m dipole position were analyzed in 40 and 90 hemispheres, respectively. The sources were localized bilaterally on the superior temporal plane with no statistical difference in position (Fig. 2). The present study found no statistical difference between the P30m, P50m, and N100m source positions.

## 4 Discussion

Previous findings of the relative position of N100m and the preceding components have been contradictory. Reite et al. [8] speculated that the M50 (=P50m) source was located in the planum temporale, posterior to the primary auditory cortex in Heschl's gyrus. Reite et al. [9] later reported that the M100 (=N100m) source is in Heschl's gyrus, using a seven-channel MEG system with MR imaging in 9 subjects, but did not directly discuss the relative positions of P50m and N100m. However, these findings show that the P50m source is posterior to the N100m source. In contrast, Pekkonen et al. [7], Yoshiura et al. [5], and Onitsuka et al. [6] reported that the N100m source was posterior to the preceding components. Pelizzone et al. [4] reported that the P30m source was localized anterior to the N100m source. However, the differences between the N100m and P50m sources and the N100m and P30m sources were minimal, or not described. Limited numbers of channels, i.e., one or seven, are likely to lead to positioning errors using MEG sensors. McEvoy et al. [3] first used a helmet-shaped 122 channel system for the comparison, and indicated that the source locations of the P50m as well as the P30m were anterior and inferior to the source of the N100m, but only in some subjects. Variable source localization was observed for the different components of the AEFs. There are some previous studies on AEFs showing no difference in the P40m (probably equivalent to our P50m) and N100m locations for click [10] and noise burst [11] stimuli.

Liégeois-Chauvel et al. [12] measured auditory evoked potentials using intracerebral recording in Heschl's gyrus and the planum temporale. They found that the 30 ms component is generated in the dorso-postero-medial part of Heschl's gyrus (primary area) and the 50 ms component is generated laterally in the primary area. They hypothesized that the 100 ms component is located posterior to the P30m or P50m sources. However, polarity reversal of these intracerebral activities was highly variable among subjects, and we believe it is too early to conclude their source localization. Our present data suggest that the sources of P30m, P50m, and N100m are at least partly colocated in the cortex, but are not generated in discrete areas.

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